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**Occurrences of *Anguillicoloides crassus*, an invasive parasitic nematode, infecting American eel (*Anguilla rostrata*) collected from New Brunswick and Nova Scotia Rivers: 2008-2009**

**Présence d'*Anguillicoloides crassus*, nématode parasite envahissant, qui infecte les anguilles d'Amérique (*Anguilla rostrata*) recueillies dans les rivières du Nouveau-Brunswick et de la Nouvelle-Écosse : 2008-2009**

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**ABSTRACT**

The exotic swim bladder nematode (*Anguillicoloides crassus*) is widespread among American eel (*Anguilla rostrata*) inhabiting the coastal and inland waters of the eastern United States, and has recently been detected in New Brunswick (NB) and Nova Scotia (NS) waters. There is concern that this parasite, which can damage the swim bladder of the American eel hosts, could potentially reduce the ability of infected adult eels to migrate and spawn successfully in the Sargasso Sea. To better understand the distribution of *A. crassus* within the waterways of NB and NS, 1,965 eels were collected for necropsy during the years 2008 and 2009, from 177 sites distributed among 61 river drainages. In total, *A. crassus* were found in the swim bladders of 49 eels collected from 22 of the sites and 8 drainages. Prevalence (P) of infection was higher among NB samples (38 of 479 eels; P = 7.9%) than NS samples (11 of 1,486 eels; P = 0.7%). Mean intensity (number of *A. crassus* per infected eel) was generally low, 2.3 for all samples combined and 2.6 and 1.5 for NB and NS samples, respectively. The number of *A. crassus* per eel was 3 or less in 90% of the cases where it was detected. All detected occurrences of *A. crassus* identified in NB were within the Saint John River, where prevalence was estimated at 10.1%, and at least 1 eel at 15 sites was infected. Information from all available sources indicates that both prevalence and intensity of *A. crassus* may be higher in tidal waters than in freshwater, but additional work will be required to affirm that this is the case.

## RÉSUMÉ

Le nématode exotique de la vessie gazeuse (*Anguillicoloides crassus*) est très répandu chez les anguilles d'Amérique (*Anguilla rostrata*), vivant dans les eaux côtières et intérieures de l'est des États-Unis, et on a détecté sa présence récemment dans les eaux du Nouveau-Brunswick (N.-B.) et de la Nouvelle-Écosse (N.-É.). On s'inquiète que ce parasite, qui peut endommager la vessie gazeuse des anguilles d'Amérique hôtes, pourrait agir sur la capacité des anguilles infectées de migrer et de frayer avec succès dans la mer des Sargasses. Afin de mieux comprendre la répartition d'*A. crassus* au sein des cours d'eau du N.-B. et de la N.-É., on a recueilli 1 965 anguilles afin de mener des autopsies de 2008 à 2009 à partir de 177 sites répartis dans 61 bassins versants. Au total, on a retrouvé *A. crassus* dans la vessie gazeuse de 49 anguilles recueillies à partir de 22 des sites et 8 bassins versants. La prévalence (P) de l'infection était plus élevée dans les échantillons du N.-B. (38 anguilles sur 479 ; P = 7,9 %) que dans ceux de la N.-É. (11 anguilles sur 1 486 ; P = 0,7 %). L'intensité moyenne (nombre d'*A. crassus* par anguille infectée) était généralement basse, soit de 2,3 pour tous les échantillons combinés et de 2,6 et 1,5 pour le N.-B. et la N.-É., respectivement. Le nombre d'*A. crassus* par anguille était de 3 ou moins dans 90 % des cas où il a été détecté. Les nématodes *A. crassus* détectés au N.-B. provenaient tous de la rivière Saint-Jean, où la prévalence a été estimée à 10,1 %, et il y avait au moins 1 anguille de 15 sites qui était infectée. L'information de l'ensemble des sources accessibles indique que la prévalence et l'intensité d'*A. crassus* pourraient être plus élevées dans les eaux de marée que dans les eaux douces, mais il faut mener d'autres travaux pour confirmer cette affirmation.

## INTRODUCTION

The American eel (*Anguilla rostrata*) is a species of ecological, economic and social importance within the Maritime Provinces of Canada. In 2006, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the American eel as a species of "Special Concern", citing pronounced declines in abundance in the Upper and Lower St. Lawrence River and Lake Ontario since the 1970s, as well as the uncertainty of the status of American eel elsewhere in Canada. The report further noted that the exotic swim bladder nematode parasite, *Anguillicoloides crassus* (Kuwahara et al. 1974, Moravec and Taraschewski 1988), widespread among USA eel populations (Johnson et al. 1995, Fries et al. 1996, Barse et al. 2001, Moser 2001) but not detected in Canada as of 2006, may represent a potential threat (COSEWIC 2006).

American eels hosting the nematode have potential to sustain injury during the parasite's attachment and feeding while in the swim bladder, and instances of parasites in high intensities, thus presumably lessening the functionality of the swim bladder. Much of the specific information concerning the pathological effects of the parasite is based upon investigations of infected European eels. Effects include: capillary hemorrhages (Molnar et al. 1993), bloody fluid and dead tissue of nematodes within the swim bladder (Molnar et al. 1993), parasitic nodules in the swim bladder (Molnar 1994), enlarged pneumatic ducts (Molnar et al. 1993), and thickened swim bladder walls (Molnar et al. 1993, Sokolowski and Dove 2006). These may lead to reduced foraging, lower energy reserves, and reduced swimming ability (Sprengel and Luchtenberg 1991, Palstra et al. 2007), all factors which could potentially reduce the ability of infected adult eels to migrate and spawn successfully in the Sargasso Sea (Barse and Secor 1999, Kirk 2003, Knopf 2006).

Since the time of writing of the 2006 COSEWIC status report, two independent studies have documented the presence of *A. crassus* within Canadian resident American eel. Aieta and Oliveira (2009) documented the presence of the parasite in eels sampled during 2007 from commercial catches from the Saint John and Tantramar rivers, New Brunswick (NB), the St. Mary's River, Nova Scotia (NS), and the tidal Bras D'Or Lakes and Margaree Harbour, Cape Breton Island, NS. Eels sampled by Rockwell et al. (2009) from the tidal portions of Mira River and Sydney Harbour, Cape Breton, NS, also during 2007, were found to be hosting *A. crassus*. None of the yellow phase eels collected via electrofishing in running freshwater on several southwestern NS rivers, were infected (Aieta and Oliveira 2009). In combination, these results suggested a discontinuous, patchy distribution for the parasite among the waterways and estuaries of the Canadian Maritime Provinces.

To better understand the present distribution of *A. crassus* within the waterways of NB and NS, eels were collected from a multitude of rivers and estuaries during 2008 and 2009. The principle source of samples was collected through eel by-catch from juvenile salmonid electrofishing surveys of the Atlantic salmon rivers. Additional sources included directed electrofishing for eels in rivers not included in the juvenile salmonids survey, opportunistic collections from downstream bypass facilities located in hydroelectric dams, rotary screw traps, beach seine surveys, and directed sampling of commercial catches.

## MATERIALS AND METHODS

### COLLECTIONS

#### Electrofishing

American eel were collected throughout the Gulf and Maritime Regions of Nova Scotia and New Brunswick during 2008 and 2009, as by-catch from the Department of Fisheries and Oceans (DFO) juvenile salmonid assessments. Briefly, backpack electrofishers were used to sample riffle habitat. All eels captured, to a maximum of 35 per site, were retained, euthanized with an overdose of a clove oil (Eugenol) – ethanol mix, and placed on ice until transferred to a freezer (-15°C) at the end of the day.

#### Other Sources

Additional samples of American eel were acquired by a variety of means in order to improve the spatial coverage of the study. Collection platforms, timing, and locations were as follows:

- Rotary screw trap installed on Little Southwest Miramichi River, a tributary to the Northwest Miramichi River (Gulf-NB) during May, 2008.
- Directed electrofishing for American eel during the summer of 2009 in the Shubenacadie, Cornwallis, and Gaspereau rivers, inner Bay of Fundy, NS.
- Down stream bypass facilities installed in hydroelectric dams located at Morgan's Falls, LaHave River, NS (May, 2009) and Ruth Falls, East River Sheet Harbour, NS (September-October, 2009).
- Young of the year striped bass (*Morone saxatilis*) beach seine survey of the tidal Shubenacadie-Stewiacke River, Cobequid Bay and Minas Basin, NS, during July-September, 2009.
- Commercial catches from the tidal portions of the Stewiacke River, inner Bay of Fundy, NS, during September, 2009.

Samples were euthanized and stored as previously described for the electrofished samples.

### LABORATORY PROTOCOL

Most specimens were processed within one year of capture. Eels were removed from freezer storage and placed in a chilled water bath overnight to thaw. Each eel was examined externally for colour phase (yellow/silver), injuries, vent irritations and any physical deformities prior to measuring total length (cm) and total weight (0.1 g). An incision was made along the ventral axis of the eel, from below the gill to the anal vent. The visceral cavity was visually inspected. Any parasites present were removed and preserved in 95% ethanol. The swim bladder was removed and opened. All parasites visible under a dissection microscope were removed and stored in 95% ethanol for later taxonomic identification.

Parasites were identified as *A. crassus* following the criteria by Moravec (1994; Appendix 1). All specimens were identified by D.M Campbell and confirmed by an independent examination by D.K. Cone (Department of Biology, Saint Mary's University, Halifax, NS) prior to calculations of

prevalence (percentage of eels infected) and mean intensity (number of *A. crassus* per infected eel; Bush et al. 1997).

The results were reported by drainage and organized by province (NB or NS) and geographic areas (Fig. 1), which were defined as follows:

1. NB-Outer Bay of Fundy (oBoF): Maine-New Brunswick border to Mispic,
2. NB-Inner Bay of Fundy (iBoF): Mispic to NB-NS border,
3. NS-iBoF: NB-NS border to Kings-Annapolis counties line,
4. NS-oBoF: Kings-Annapolis Counties line to Digby-Yarmouth counties line ,
5. NS-Atlantic: Digby-Yarmouth counties line to Canso Causeway,
6. NS-Eastern Cape Breton Island (ECB): eastern side of the Canso Causeway to Cape North,
7. NS-Western Cape Breton Island (WCB): Cape North to western side of the Canso Causeway,
8. NS-Gulf of St. Lawrence (Gulf): western side of the Canso Causeway to NS-NB border, and
9. NB-Gulf: NS-NB border to NB-Québec border (10).

## RESULTS

In total, *A. crassus* were found in the swim bladders of 49 of 1,965 eels (Prevalence (P) = 2.5%) collected from 177 sites distributed among 61 drainages (Table 1; Fig. 2). The parasite was documented as present in 22 different sites among 8 drainages (Table 1; Fig. 2): 4 drainages within NS-Atlantic, and one each within the NS-Gulf, NS-WCB, NS-iBoF, and NB-oBoF areas. Attempts to collect eels via electrofishing in NS-ECB drainages were not successful.

Prevalence of infection was higher among NB samples (38 of 479 eels; P = 7.9%) than NS samples (11 of 1,486 eels; P = 0.7%; Table 1). Mean intensity ( $\pm 1$  standard deviation), was generally low,  $2.3 \pm 3.8$  for all samples combined and  $2.6 \pm 4.0$  and  $1.5 \pm 0.7$  for NB and NS samples, respectively (Table 1). The number of *A. crassus* per eel was 3 or less in 90% of the cases where it was detected (Fig. 3).

All detected occurrences of *A. crassus* within NB were within the Saint John River (Table 2; Fig. 3), where at least 1 eel at 15 sites was infected. The prevalence and mean ( $\pm$  standard deviation) intensity of infection were 10.1% and  $2.5 \pm 4.1$  nematodes per eel, respectively (Table 2). *A. crassus* was detected in 7 of 9 Saint John River tributaries located downstream of Mactaquac Dam (Table 3). Few (n=3) eels were collected from the 3 tributaries sampled upstream of Mactaquac Dam (Table 3).

Electrofishing activities in NS during 2008 and 2009 yielded 1,441 eels from 113 sites distributed among 55 NS drainages. Sampling via other methods raised the total number of eel available to 1,486 eels. In total, 11 eels from 7 drainages were found to be carrying *A. crassus* (Tables 2, 4, 5; Fig. 3). Prevalence varied between 1.1% and 27.3% when the parasite was present (Tables 4,5; Fig. 4), with one site found to have a prevalence of 100% in West River (Antigonish; NS-Gulf; Table 5). However, the sample was small (n=2; Table 5).

Overall, both prevalence and mean intensity of *A. crassus* was higher in NB samples, specifically among Saint John River samples, than for NS samples (Figs. 4, 5).

The occurrence of *A. crassus*, reported previously by Aieta and Oliveira (2009), in the St. Mary's River, NS, and the Saint John River, NB (Table 6) were corroborated with electrofished samples

(Tables 2, 4). Attempts to collect eel from Margaree River (NS-WCB), where the parasite had been documented by Aieta and Oliveira (2009) (Table 6) as present in tidal waters, were not successful.

Nova Scotia – Outer Bay of Fundy was the only geographic area with no detected occurrences of *A. crassus* (Table 5); however, the search effort was relatively low (drainages = 2, sites = 6, eels = 49).

## DISCUSSION

This study was able to successfully identify the presence of *A. crassus* within American eel collected principally as a by-catch of DFO electrofishing salmonid surveys. However, it was frequently not possible to acquire a minimum sample size of 35 eel per site, using collection protocols designed to assess juvenile salmonids, because of substantive natural variability in eel abundance among sites and among drainages. Low availability of eels was particularly pronounced in the sampled freshwater areas of Cape Breton (Fig. 2).

The data compiled for 2008 and 2009 indicate that, for freshwater resident American eel, parasite occurrence (as measured by number of river drainages), prevalence and intensity are low at present. However, future work should incorporate information on catchment area in order to estimate the true proportion of the freshwater-resident population that is either exposed to or infected by *A. crassus*. For example, the Saint John River, only 1 of the 61 discrete drainages sampled, represents a high proportion of the freshwater habitat that is available to eel in the Maritimes Region<sup>1</sup>.

The underlying basis for the apparent patchy freshwater distribution of the parasite, both among drainages and among-sites within drainages, is not clear at the present time. Extensive gaps in the distribution of the parasite relative to the coast line is not consistent with a progressive northward extension from USA waters. A recent survey revealed a largely contiguous distribution from Rhode Island to southern Maine (Aieta and Oliveira 2009) with a higher intensity of infection (7 to 76%; Aieta and Oliveira 2009) than found in the present study. However, a study of Hudson River eels (Machut and Limburg 2008) indicated that infestation rates were lower in inland waters, possibly because transmission from secondary hosts was reduced (Schmidt et al. 2009). The combined information from all studies (Table 6) does tend to suggest that the prevalence and intensity of *A. crassus* infections are higher in tidal waters than in fresh water, but additional work will be required to affirm that this is the case.

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<sup>1</sup> At the time of writing, drainage area information is available for most Nova Scotia rivers, but not for Bay of Fundy-New Brunswick rivers.

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Table 1. Summary of collection activities and recorded presence of *Anguillicoloides crassus* by year, province and area.

| Year                | Province | Area <sup>1</sup> | Drainages         |         | Sites             |         | Eels              |         | Prevalence<br>(%) | Intensity |           |
|---------------------|----------|-------------------|-------------------|---------|-------------------|---------|-------------------|---------|-------------------|-----------|-----------|
|                     |          |                   | <i>A. crassus</i> |         | <i>A. crassus</i> |         | <i>A. crassus</i> |         |                   | Mean      | SD        |
|                     |          |                   | Sampled           | Present | Sampled           | Present | Sampled           | Present |                   |           |           |
| 2009                | NB       | iBoF              | 1                 | 0       | 6                 | 0       | 16                | 0       | 0.0               |           |           |
| 2009                | NB       | oBoF <sup>2</sup> | 4                 | 1       | 47                | 15      | 423               | 38      | 9.0               |           |           |
| 2008                | NB       | Gulf              | 1                 | 0       | 1                 | 0       | 40                | 0       | 0.0               |           |           |
| New Brunswick Total |          |                   | 6                 | 1       | 54                | 15      | 479               | 38      | 7.9               | 2.6 (1.6) | 4 (2.2)   |
|                     |          |                   |                   |         |                   |         |                   |         |                   |           |           |
| 2008-09             | NS       | Atlantic          | 45                | 4       | 103               | 4       | 1,354             | 4       | 0.3               | 1.8 (1.7) | 0.5 (1.4) |
| 2008-09             | NS       | Gulf              | 2                 | 1       | 2                 | 1       | 7                 | 2       | 28.6              | 2.0       |           |
| 2008-09             | NS       | iBoF              | 5                 | 1       | 11                | 1       | 65                | 2       | 3.1               | 1.0       |           |
| 2008                | NS       | oBoF              | 2                 | 0       | 6                 | 0       | 49                | 0       | 0.0               |           |           |
| 2008                | NS       | WCB               | 1                 | 1       | 1                 | 1       | 11                | 3       | 27.3              | 1.3       | 0.60      |
| Nova Scotia Total   |          |                   | 55                | 7       | 123               | 7       | 1,486             | 11      | 0.7               | 1.5 (1.4) | 0.7 (1.5) |
|                     |          |                   |                   |         |                   |         |                   |         |                   |           |           |
| Grand Total         |          |                   | 61                | 8       | 177               | 22      | 1,965             | 49      | 2.5               | 2.3 (1.6) | 3.8 (2.1) |

<sup>1</sup> iBoF = inner Bay of Fundy, oBoF = outer Bay of Fundy, Gulf = Gulf of St. Lawrence, Atlantic = Atlantic Coast, WCB = Western Cape Breton<sup>2</sup> 12 sub-drainages within the Saint John River were sampled

Table 2. Summary of New Brunswick river drainages sampled for eels, the number of sites sampled per drainage, number of sites where *A. crassus* were present, the number of eels necropsied and determined to be hosting *A. crassus* and estimates of *A. crassus* prevalence and intensity of infection. The estimated geometric mean intensity is in brackets.

| Year | Province | Area <sup>1</sup> | River<br>Drainage | Capture<br>Method <sup>2</sup> | Sites             |         | Eels              |         | Prevalence<br>(%) | Intensity |         |
|------|----------|-------------------|-------------------|--------------------------------|-------------------|---------|-------------------|---------|-------------------|-----------|---------|
|      |          |                   |                   |                                | <i>A. crassus</i> |         | <i>A. crassus</i> |         |                   | Mean      | SD      |
|      |          |                   |                   |                                | Sampled           | Present | Sampled           | Present |                   |           |         |
| 2009 | NB       | iBoF              | Big Salmon River  | EF                             | 6                 | 0       | 16                | 0       | 0.0               | 2.6 (1.6) | 4 (2.2) |
| 2009 | NB       | oBoF              | Digdeguash        | EF                             | 2                 | 0       | 2                 | 0       | 0.0               |           |         |
| 2009 | NB       | oBoF              | New River         | EF                             | 2                 | 0       | 3                 | 0       | 0.0               |           |         |
| 2009 | NB       | oBoF              | Saint John River  | EF                             | 40                | 15      | 375               | 38      | 10.1              |           |         |
| 2009 | NB       | oBoF              | St. Croix River   | EF                             | 3                 | 0       | 43                | 0       | 0.0               |           |         |
|      |          |                   | Area Total        |                                | 47                | 15      | 423               | 38      | 9.0               |           |         |
| 2008 | NB       | Gulf              | Miramichi River   | RST                            | 1                 | 0       | 40                | 0       | 0.0               |           |         |
|      |          |                   | Total             |                                | 54                | 15      | 479               | 38      | 7.9               | 2.6 (1.6) | 4 (2.2) |

<sup>1</sup> iBoF = inner Bay of Fundy, oBoF = outer Bay of Fundy, Gulf = Gulf of St. Lawrence

<sup>2</sup> EF = Electrofishing, RST = Rotary Screw Trap

Table 3. Summary of Saint John River tributaries sampled for eels, the number of sites sampled per drainage, number of sites where *A. crassus* were present, the number of eels necropsied and determined to be hosting *A. crassus* and estimates of *A. crassus* prevalence and intensity of infection. The estimated geometric mean intensity is in brackets.

| Year                   | Province | River<br>Drainage  | Capture<br>Method <sup>1</sup> | Sites   |                              | Eels    |                              | Prevalence<br>(%) | Intensity |                     |
|------------------------|----------|--------------------|--------------------------------|---------|------------------------------|---------|------------------------------|-------------------|-----------|---------------------|
|                        |          |                    |                                | Sampled | <i>A. crassus</i><br>Present | Sampled | <i>A. crassus</i><br>Present |                   | Mean      | SD                  |
|                        |          |                    |                                |         |                              |         |                              |                   |           |                     |
| Above Mactaquac Dam    |          |                    |                                |         |                              |         |                              |                   |           |                     |
| 2009                   | NB       | Mactaquac Stream   | EF                             | 1       | 0                            | 1       | 0                            | 0.0               |           |                     |
| 2009                   | NB       | Nackawic River     | EF                             | 1       | 0                            | 1       | 0                            | 0.0               |           |                     |
| 2009                   | NB       | Pokiok Stream      | EF                             | 1       | 0                            | 1       | 0                            | 0.0               |           |                     |
|                        |          | <i>Sub-Total</i>   |                                | 3       | 0                            | 3       | 0                            | 0.0               |           |                     |
| Below Mactaquac Dam    |          |                    |                                |         |                              |         |                              |                   |           |                     |
| 2009                   | NB       | Coal Creek         | EF                             | 3       | 2                            | 20      | 10                           | 50.0              | 1.8 (1.5) | 1.2 (1.8)           |
| 2009                   | NB       | Jemseg River       | EF                             | 3       | 2                            | 32      | 4                            | 12.5              | 1.0       | 0.00                |
| 2009                   | NB       | Kennebecasis River | EF                             | 1       | 1                            | 5       | 2                            | 40.0              | 1.0       |                     |
| 2009                   | NB       | Keswick River      | EF                             | 4       | 1                            | 27      | 1                            | 3.7               | 2.0       |                     |
| 2009                   | NB       | Nashwaak River     | EF                             | 9       | 0                            | 78      | 0                            | 0.0               |           |                     |
| 2009                   | NB       | Nashwaaksis Brook  | EF                             | 2       | 1                            | 39      | 2                            | 5.1               | 1.0       |                     |
| 2009                   | NB       | Nerepis River      | EF                             | 3       | 2                            | 13      | 2                            | 15.4              | 2.0       |                     |
| 2009                   | NB       | Noonan Stream      | EF                             | 1       | 0                            | 5       | 0                            | 0.0               |           |                     |
| 2009                   | NB       | Oromocto River     | EF                             | 9       | 5                            | 136     | 12                           | 8.8               | 2.1 (1.4) | 3.1 (2.1)           |
|                        |          | <i>Sub-Total</i>   |                                | 35      | 14                           | 0       | 355                          | 33                | 9.3       | 2.6 (1.6) 4.0 (2.2) |
| Saint John River Total |          |                    |                                | 38      | 14                           | 0       | 358                          | 33                | 9.2       | 2.6 (1.6) 4.0 (2.2) |

<sup>1</sup> EF = Electrofishing

Table 4. Summary of Atlantic Coast Nova Scotia drainages sampled for eels, the number of sites sampled per drainage, number of sites where *A. crassus* were present, the number of eels necropsied and determined to be hosting *A. crassus* and estimates of *A. crassus* prevalence and intensity of infection. The estimated geometric mean intensity is in brackets.

| Year       | Province | Area        | River<br>Drainage            | Capture<br>Method <sup>1</sup> | Sites             |         | Eels              |         | Prevalence<br>(%) | Intensity |           |
|------------|----------|-------------|------------------------------|--------------------------------|-------------------|---------|-------------------|---------|-------------------|-----------|-----------|
|            |          |             |                              |                                | <i>A. crassus</i> |         | <i>A. crassus</i> |         |                   | Mean      | SD        |
|            |          |             |                              |                                | Sampled           | Present | Sampled           | Present |                   |           |           |
| 2008       | NS       | NS-Atlantic | Annis River                  | EF                             | 2                 | 0       | 71                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Blacks Brook (Shelburne)     | EF                             | 1                 | 0       | 8                 | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Chegoggin River              | EF                             | 1                 | 0       | 4                 | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Clyde River                  | EF                             | 1                 | 0       | 19                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | East River - Chester         | EF                             | 2                 | 0       | 20                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | East River - Lockport        | EF                             | 1                 | 0       | 4                 | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | East River - Tantallon       | EF                             | 1                 | 0       | 11                | 0       | 0.0               |           |           |
| 2009       | NS       | NS-Atlantic | East River - Sheet Harbour   | FW                             | 2                 | 0       | 16                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Ecum Secum River             | EF                             | 4                 | 0       | 34                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Gaspereau Brook              | EF                             | 1                 | 0       | 16                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Gegogan Brook                | EF                             | 1                 | 0       | 32                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Gold River                   | EF                             | 5                 | 0       | 17                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Granite Village Brook        | EF                             | 1                 | 0       | 4                 | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Halfway Brook                | EF                             | 1                 | 0       | 13                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Indian River                 | EF                             | 1                 | 0       | 2                 | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Ingram River                 | EF                             | 3                 | 0       | 43                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Jordan River                 | EF                             | 1                 | 0       | 11                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Kiack Brook                  | EF                             | 1                 | 0       | 10                | 0       | 0.0               |           |           |
| 2009       | NS       | NS-Atlantic | Lalave River                 | FW                             | 1                 | 0       | 14                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Martin's River               | EF                             | 2                 | 0       | 51                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Medway River                 | EF                             | 3                 | 1       | 37                | 1       | 2.7               | 2.0       |           |
| 2008       | NS       | NS-Atlantic | Mersey River                 | EF                             | 2                 | 1       | 40                | 1       | 2.5               | 1.0       |           |
| 2008       | NS       | NS-Atlantic | Mosher River                 | EF                             | 2                 | 0       | 28                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Mushamush River              | EF                             | 3                 | 0       | 26                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Musquodoboit River           | EF                             | 1                 | 0       | 1                 | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Nine Mile River              | EF                             | 1                 | 0       | 6                 | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Petite Riviere               | EF                             | 1                 | 0       | 22                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Pumey Brook                  | EF                             | 1                 | 0       | 12                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Quoddy River                 | EF                             | 4                 | 0       | 76                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Rodney Brook                 | EF                             | 1                 | 0       | 10                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Roseway River                | EF                             | 1                 | 0       | 10                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Sable River                  | EF                             | 2                 | 0       | 26                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Salmon River (Digby)         | EF                             | 3                 | 0       | 70                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Salmon River (Halifax)       | EF                             | 3                 | 0       | 8                 | 0       | 0.0               |           |           |
| 2008-09    | NS       | NS-Atlantic | Salmon River (Lake Echo)     | EF                             | 6                 | 1       | 120               | 1       | 0.8               | 2.0       |           |
| 2008       | NS       | NS-Atlantic | Salmon River (Port Dufferin) | EF                             | 1                 | 0       | 2                 | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Ship Harbour River           | EF                             | 1                 | 0       | 20                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Smith Brook                  | EF                             | 1                 | 0       | 8                 | 0       | 0.0               |           |           |
| 2008-09    | NS       | NS-Atlantic | St. Mary's River             | EF                             | 14                | 1       | 167               | 1       | 0.6               | 2.0       |           |
| 2008       | NS       | NS-Atlantic | Tangier River                | EF                             | 3                 | 0       | 62                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Tidney River                 | EF                             | 1                 | 0       | 5                 | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | Tusket River                 | EF                             | 7                 | 0       | 86                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | West Brook (Porter's Lake)   | EF                             | 3                 | 0       | 48                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | West River - Sheet Harbour   | EF                             | 3                 | 0       | 54                | 0       | 0.0               |           |           |
| 2008       | NS       | NS-Atlantic | West Taylor Bay Brook        | EF                             | 2                 | 0       | 10                | 0       | 0.0               |           |           |
| Area Total |          |             |                              |                                | 103               | 4       | 1,354             | 4       | 0.3               | 1.8 (1.7) | 0.5 (1.4) |

<sup>1</sup> EF = Electrofishing, FW = Fish Way

Table 5. Summary of Nova Scotia drainages located in the Gulf of St. Lawrence (Gulf), inner Bay of Fundy (iBoF), outer Bay of Fundy (oBoF) and Western Cape Breton (WCB) sampled for eels, the number of sites sampled per drainage, number of sites where *A. crassus* were present, the number of eels necropsied and determined to be hosting *A. crassus* and estimates of *A. crassus* prevalence and intensity of infection. The estimated geometric mean intensity is in brackets.

| Year    | Province | Area | River<br>Drainage    | Capture<br>Method <sup>1</sup> | Sites             |         | Eels              |         | Prevalence<br>(%) | Intensity |      |
|---------|----------|------|----------------------|--------------------------------|-------------------|---------|-------------------|---------|-------------------|-----------|------|
|         |          |      |                      |                                | <i>A. crassus</i> |         | <i>A. crassus</i> |         |                   | Mean      | SD   |
|         |          |      |                      |                                | Sampled           | Present | Sampled           | Present |                   |           |      |
| 2008    | NS       | Gulf | Bailey's Brook       | EF                             | 1                 | 0       | 5                 | 0       | 0.0               |           |      |
| 2009    | NS       | Gulf | West River           | EF                             | 1                 | 1       | 2                 | 2       | 100.0             | 2.0       |      |
|         |          |      | Area Total           |                                | 2                 | 1       | 7                 | 2       | 28.6              |           |      |
|         |          |      |                      |                                |                   |         |                   |         |                   |           |      |
| 2008    | NS       | iBoF | Barren Brook         | EF                             | 1                 | 0       | 7                 | 0       | 0.0               |           |      |
| 2009    | NS       | iBoF | Gaspereau River      | EF                             | 2                 | 0       | 11                | 0       | 0.0               |           |      |
| 2008-09 | NS       | iBoF | Salmon River (Truro) | EF                             | 2                 | 0       | 14                | 0       | 0.0               |           |      |
| 2009    | NS       | iBoF | Shubenacadie River   | EF/BS                          | 3                 | 0       | 20                | 0       | 0.0               |           |      |
| 2009    | NS       | iBoF | Stewiacke River      | EF                             | 3                 | 1       | 13                | 2       | 15.4              | 1.0       |      |
|         |          |      | Area Total           |                                | 11                | 1       | 65                | 2       | 3.1               |           |      |
|         |          |      |                      |                                |                   |         |                   |         |                   |           |      |
| 2008    | NS       | oBoF | Annapolis River      | EF                             | 5                 | 0       | 45                | 0       | 0.0               |           |      |
| 2008    | NS       | oBoF | Bear River           | EF                             | 1                 | 0       | 4                 | 0       | 0.0               |           |      |
|         |          |      | Area Total           |                                | 6                 | 0       | 49                | 0       | 0.0               |           |      |
|         |          |      |                      |                                |                   |         |                   |         |                   |           |      |
| 2008    | NS       | WCB  | Mill Brook           | EF                             | 1                 | 1       | 11                | 3       | 27.3              | 1.3       | 0.60 |

<sup>1</sup> EF = Electrofishing, BS = Beach Seine

Table 6. Summary of reported occurrences of *A. crassus* in American eel collected from Nova Scotia and New Brunswick.

| Year | Province | Area <sup>1</sup> | Drainage                 | Capture |         | Eels    |                           | Prevalence (%) | Intensity |     | Source               |
|------|----------|-------------------|--------------------------|---------|---------|---------|---------------------------|----------------|-----------|-----|----------------------|
|      |          |                   |                          | Method  | Habitat | Sampled | <i>A. crassus</i> Present |                | Mean      | SD  |                      |
| 2007 | NB       | iBoF              | Tantramar River          | CS      | FW      | 32      | 1                         | 3.1            | 1         | -   | Aieta et al. 2009    |
| 2007 | NB       | oBoF              | Saint John River         | CS      | FW      | 28      | 1                         | 3.6            | 1         | -   | Aieta et al. 2009    |
| 2009 | NB       | oBoF              | Saint John River         | EF      | FW      | 375     | 38                        | 10.1           | 2.6       | 4   | This report          |
| 2008 | NS       | Atlantic          | Medway River             | EF      | FW      | 37      | 1                         | 2.7            | 2         | -   | This report          |
| 2008 | NS       | Atlantic          | Mersey River             | EF      | FW      | 40      | 1                         | 2.5            | 1         | -   | This report          |
| 2008 | NS       | Atlantic          | Salmon River (Lake Echo) | EF      | FW      | 120     | 1                         | 0.8            | 2         | -   | This report          |
| 2007 | NS       | Atlantic          | St. Mary's River         | CS      | FW      | 37      | 4                         | 14.8           | 2.5       | -   | Aieta et al. 2009    |
| 2008 | NS       | Atlantic          | St. Mary's River         | EF      | FW      | 167     | 1                         | 0.6            | 2         | -   | This report          |
| 2007 | NS       | ECB               | Bras D'Or Lakes          | CS      | Tidal   | 28      | 4                         | 14.3           | 4         | -   | Aieta et al. 2009    |
| 2008 | NS       | ECB               | Mira River               | EP      | Tidal   | 10      | 6                         | 60             | 2.7       | 2.3 | Rockwell et al. 2009 |
| 2008 | NS       | ECB               | Sydney River             | EP      | Tidal   | 5       | 1                         | 20             | 11        | -   | Rockwell et al. 2009 |
| 2007 | NS       | iBoF              | Stewiacke River          | EP      | Tidal   | 12      | 2                         | 16.7           | 1         | -   | This report          |
| 2007 | NS       | Gulf              | Margaree River           | CS      | Tidal   | 26      | 8                         | 30.8           | 6.1       | -   | Aieta et al. 2009    |
| 2009 | NS       | Gulf              | West River (Antigonish)  | EF      | FW      | 2       | 2                         | 100            | 2         | 1.4 | This report          |
| 2008 | NS       | WCB               | Mill Brook (Troy)        | EF      | FW      | 11      | 3                         | 27.3           | 1.3       | 0.6 | This report          |

<sup>1</sup> iBoF = inner Bay of Fundy, oBoF = outer Bay of Fundy, Atlantic = Atlantic Coast, Gulf = Gulf of St. Lawrence, WCB = Western Cape Breton

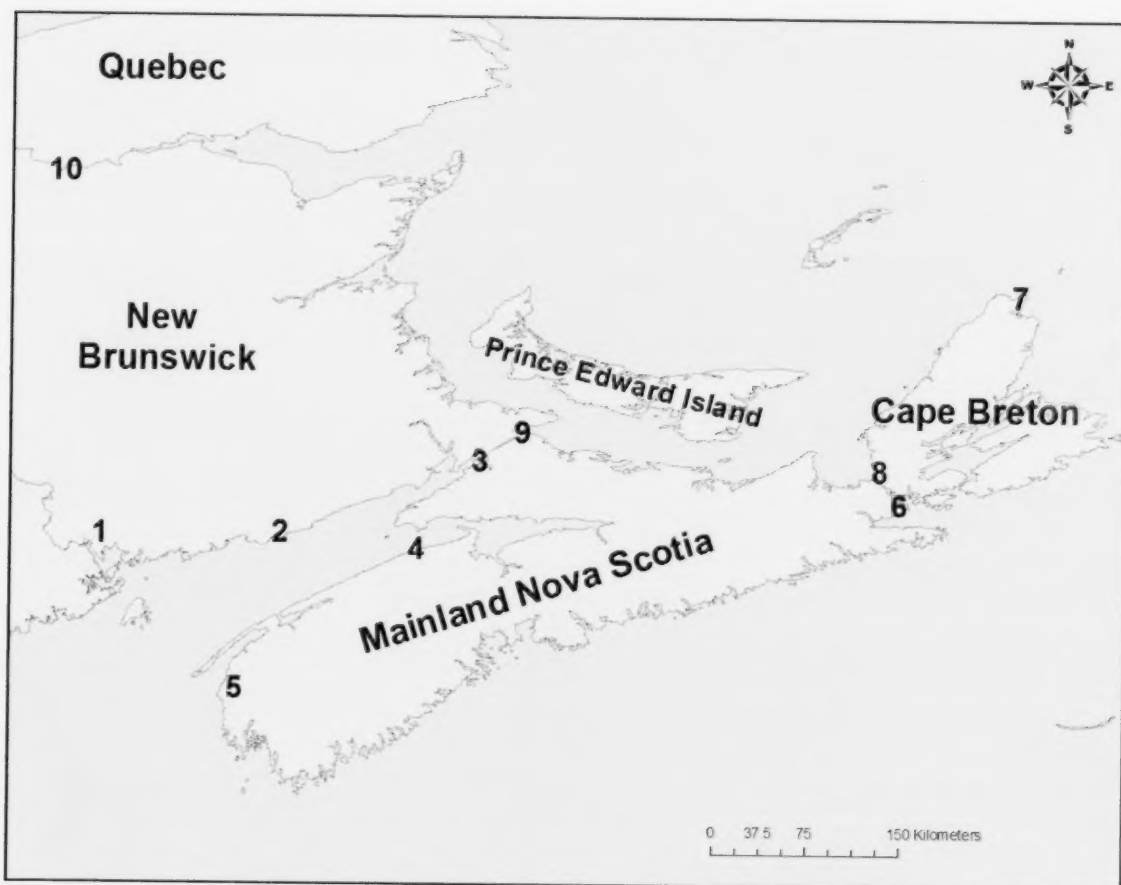


Figure 1. Map of Nova Scotia and New Brunswick, showing boundaries of the geographic areas referred to in the report.

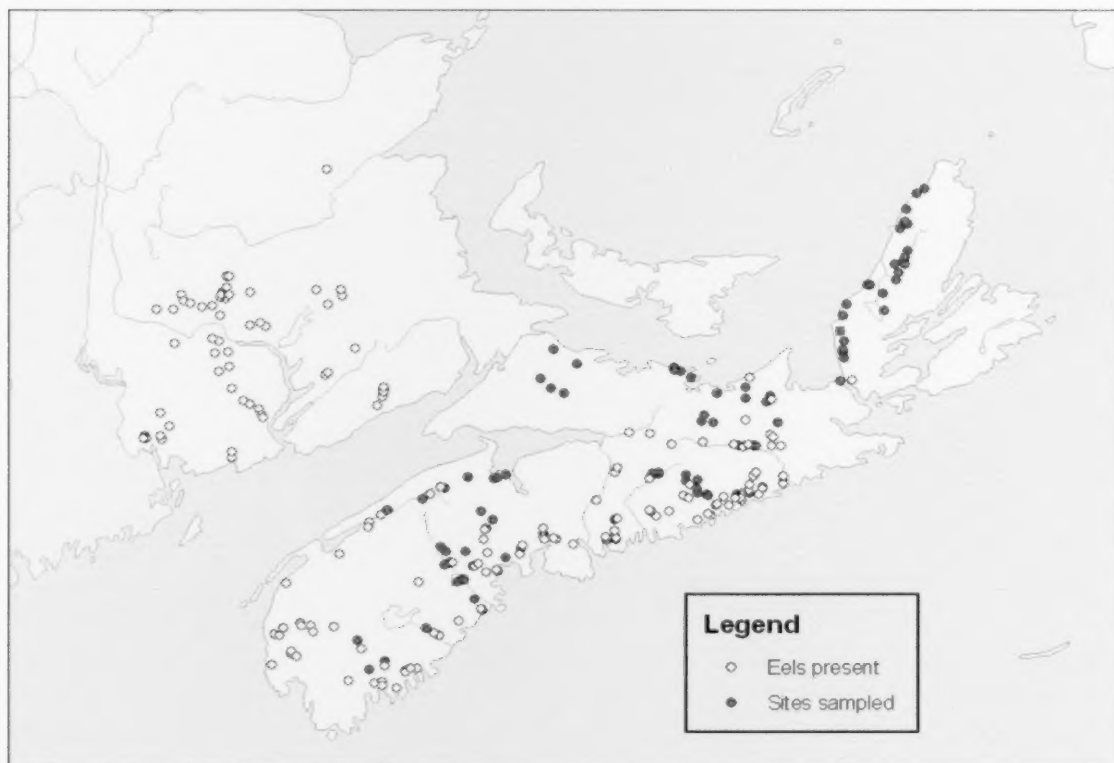


Figure 2. Location of electrofishing sites sampled and sites where eels were present (2008-2009 combined).

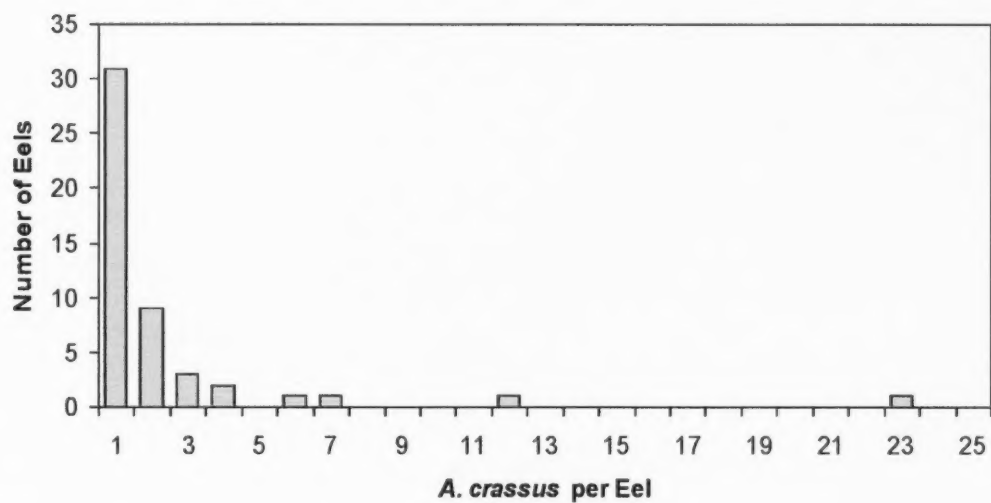


Figure 3. Frequency distribution of *A. crassus* intensity among infected eels.

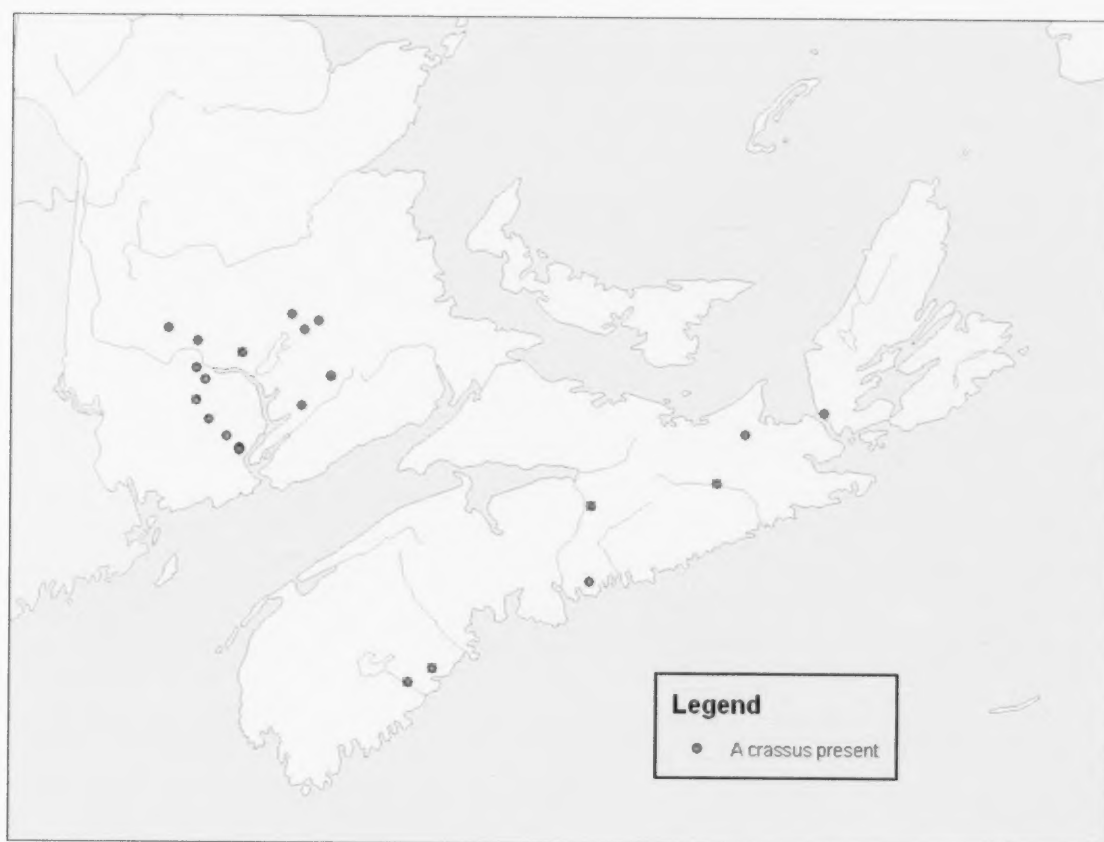


Figure 4. Location of electrofishing sites where *A. crassus* was detected.

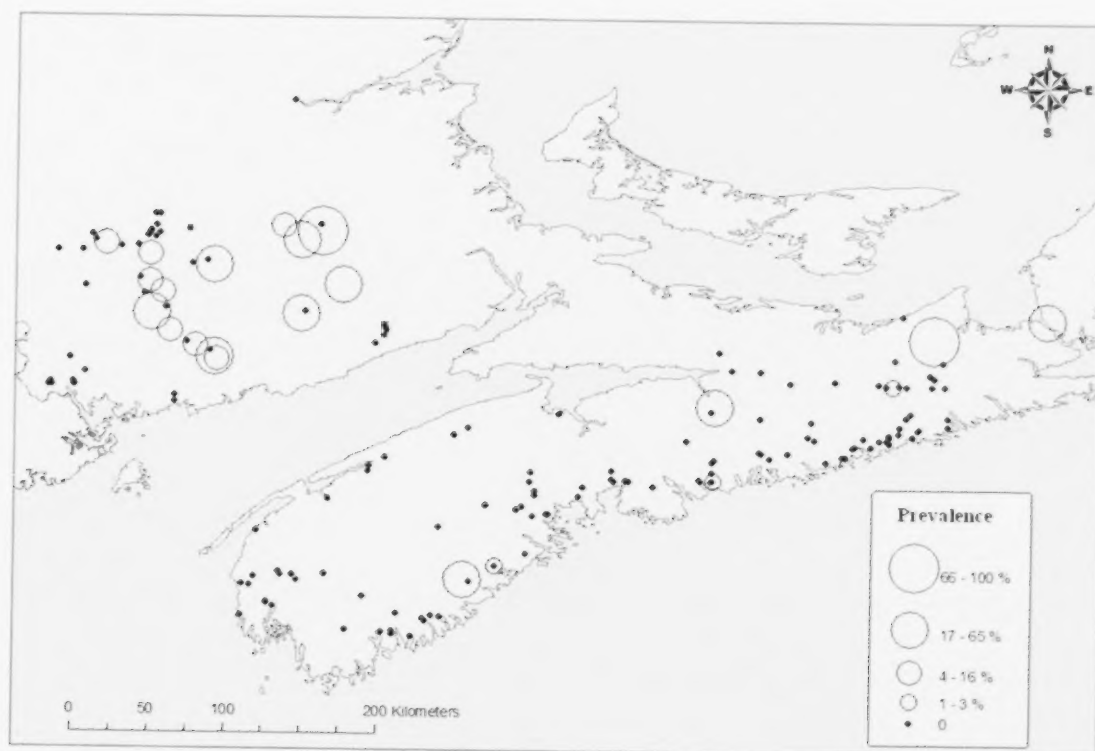


Figure 5. Locations of calculated prevalence (%) of *A. crassus* present throughout Nova Scotia and New Brunswick.

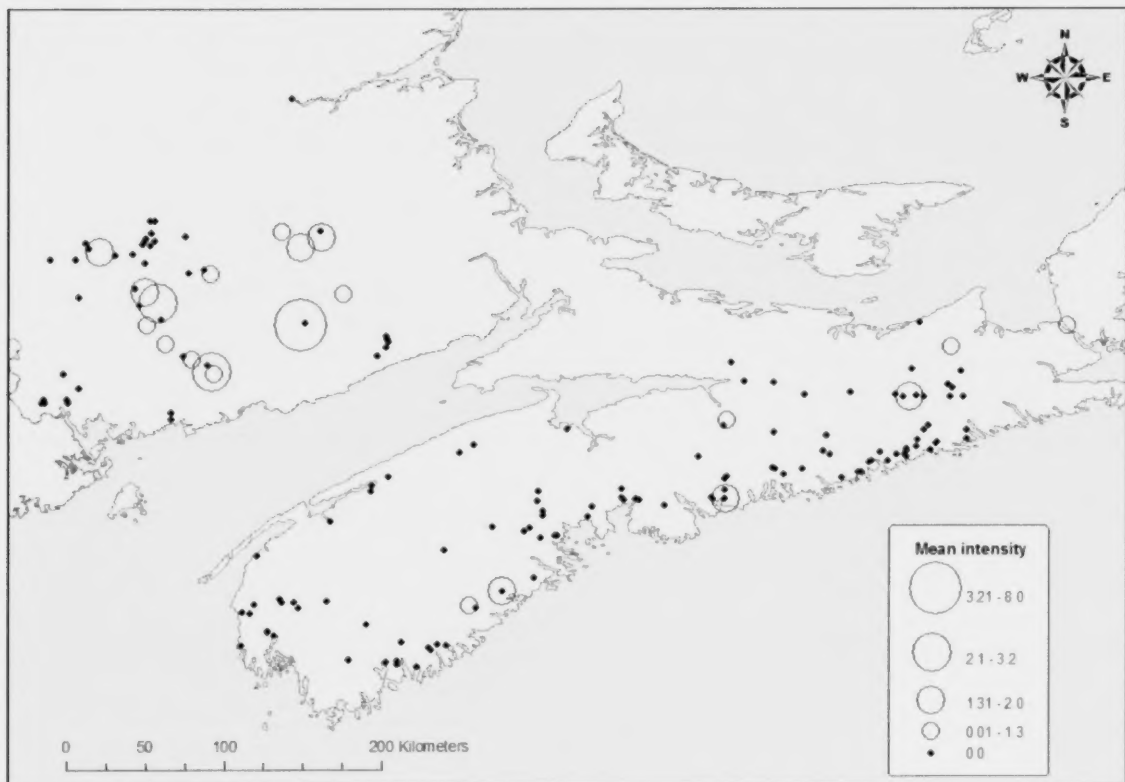


Figure 6. Locations of calculated mean intensities of *A. crassus* present throughout Nova Scotia and New Brunswick.

## APPENDIX 1

**Description of *Anguillicola (Anguillicoloides) crassus* (Kuwahara Niimi et Itagaki, 1974) from Moravec, F. 1994. Parasitic Nematodes of Freshwater Fishes of Europe. Kluwer Academic Publishers. Dordrecht, The Netherlands, pp. 223-230.**

**Description:** Body dark colored, fusiform, rather plump, tapering to both ends. Epicuticle almost smooth. Head end rounded. Mouth aperture circular, surrounded by four big dorsolateral and ventrolateral cephalic papillae and two small lateral amphids. Bucal capsule well sclerotized, its anterior rim bearing one row of 21-28 rather big circumoral teeth. Oesophagus strongly muscular, expanded at its posterior half. Valvular apparatus of oesophagus well developed. Nerve ring situated approximately at border of first and second thirds of oesophagus length, excretory pore near junction of oesophagus and intestine. Intestine dark, straight, broad, only its anterior end being usually narrowed. Three conspicuously large, oval unicellular rectal glands present; additional small ventral rectal gland also present, being frequently overlapped by large ones and, accordingly indistinct. Tail conical and short.

**Male:** Length of body 5.77 - 23.12 mm, maximum width 0.340 - 1.77 mm. Buccal capsule 0.021 - 0.027 mm long and 0.048 - 0.063 mm wide; maximum thickness of its wall 0.003 - 0.006 mm. Length of oesophagus 0.571 - 0.843 mm, its maximum width 0.135 - 0.258 mm, length of oesophageal valves 0.054 - 0.095 mm. Length ratio of oesophagus and body 1:9 - 29, distance of nerve ring and excretory pore from anterior extremity 0.210 - 0.286 mm and 0.694 - 0.924 mm, respectively. Seminal vesicle well developed, variable in size. Common cloacal duct opening on prominent process 0.048 - 0.090 mm long. Size of large rectal glands 0.122 - 0.394 x 0.082 - 0.204 mm, of small one 0.042 - 0.109 x 0.027 - 0.068 mm. Six pairs of caudal papillae present: 2 - 3 preanals, 1 adanal, 2 - 3 postanals. Tail conical, 0.109 - 0.286 mm long.

**Female:** Length of body of gravid females 13.08 - 44.74 mm, maximum width 1.22 - 5.00 mm. Buccal capsule 0.024 - 0.027 mm long and 0.054 - 0.063 mm wide; maximum thickness of its wall 0.006 mm. Length of oesophagus 0.775 - 1.09 mm, its maximum width 0.204 - 0.381 mm. Length ratio of oesophagus and body 1:15 - 40. Distance of nerve ring and excretory pore from anterior extremity 0.258 - 0.299 mm and 0.857 - 1.142 mm, respectively. Vulva prominent, cone-shaped, situated in posterior part of body, 3.40 - 7.01 mm from posterior extremity, this representing approx 1/4 - 1/10 of body length. Ovarian tubes reaching anteriorly to some distance below oesophagus end level and posteriorly to region anterior to rectal glands. Uterus occupying most space of body, containing numerous eggs, developing embryos, and fully formed, sheathed larvae 0.244 - 0.258 mm long and 0.015 mm wide. Rectum hyaline tube, opening usually on well developed papilla-like projection; latter indistinct in some species. Tail conical, 0.136 - 0.448 mm long.